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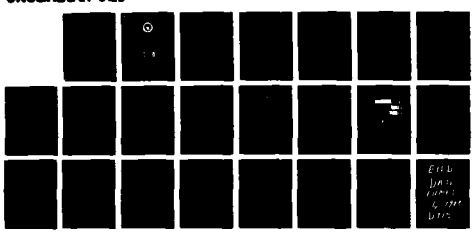

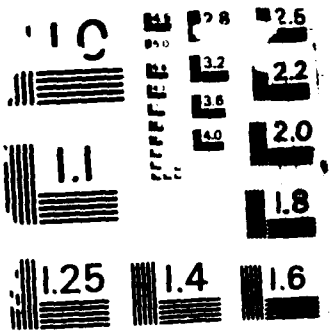

THE DEPARTMENT OF DEFENSE REPORT ON THE MERIT REVIEW PROCESS FOR COMPETITIVE SELECTION OF UNIVERSITY RESEARCH PROJECTS AND AN ANALYSIS OF THE POTENTIAL FOR EXPANDING THE GEOGRAPHIC DISTRIBUTION OF RESEARCH

FOR THE COMMITTEES ON APPROPRIATIONS
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INTRODUCTION

This report responds to the Committee on Conference request, DoD Appropriations Act, 1987 as set forth in the following:

> **With the establishment of the University Research Initiative in fiscal year 1986 and rising funds for the Strategic Defense Initiative, the Department of Defense's investment in university-based research is increasing. Consequently, the Appropriations Committees need to ensure that the peer review process for the allocation of university funding is working effectively, and that mechanisms are in place to broaden the base of DoD university research commensurate with these increasing resources.**
>
> **Therefore, the conferees direct the Department of Defense to submit a report to the Appropriations Committees by March 1, 1987, which (1) explains in detail the current peer review process in a step-by-step fashion; (2) explains current participants in this process, including peer review panels, boards, or conferences, and how such peer reviewers are evaluated and chosen; and (3) an analysis of the potential for expanding the research base into geographical areas which at the present time receive little defense-related university funding.**

The ~~first section of~~ this report explains DoD's merit review process and the participants in that process; the second section describes the current distribution of DoD research funding to universities and the potential for geographic expansion.

"MERIT" VS. "PEER" REVIEW

It should be noted at the outset that DoD prefers to use the term "merit" review, rather than "peer" review, to describe the process by which university research proposals are selected for funding. As commonly used, "peer" review implies that a university researcher's proposal is reviewed for scientific merit by other university researchers competent in the particular discipline. Moreover, it implies that the scientific merit of the proposal and the competence of the investigator are the sole criteria for award.

Using the results of an external "peer" review process as the basis for awarding university research funds would be appropriate if an agency's mission were only "to support good science." The missions of DoD, other science-intensive agencies, and even the National Science Foundation (NSF), however, are broader and more complex.

A recent advisory committee study of the NSF peer review process has found that factors in addition to the scientific merit of the proposal are increasing in importance in determining selection of proposals for funding in order to be consistent with NSF's mission. The September 25, 1986 report of the NSF Advisory Committee on Merit Review points out:

> NSF's primary criteria for selection of research projects have always been the quality of the proposed research and the competence of the investigators. Once excellence has been established secondary criteria are applied. Specifically, attention is given to the effect of the project on the research infrastructure, and to contributions to related goals of equity and distribution of resources among institutions and geographic areas. The changing scale and organization of science have increased the importance of these factors and of multiple elements in the evaluation of a proposal.

As a result of the Committee's findings, NSF has now adopted the term "merit review" to describe their selection process which entails consideration of numerous factors in awarding research funds.

From the inception of DoD programs for the support of research, scientific excellence has likewise been a necessary condition for selection of a proposal for funding. It is not, however, a sufficient condition: it is necessary that the relevance of the proposed research to the DoD mission be firmly established if it is to be funded.

Other science-intensive agencies, such as the Department of Energy, the National Institutes of Health, NASA, and the Department of Agriculture, use similar considerations of mission when making competitive selections of research to be supported. As a result, DoD and NASA support research, for example, which tends to be concentrated in the physical science and engineering disciplines, while NIH supports the life sciences and medical disciplines.

Similarly, it is often the case that one institution of higher education may elect to focus on developing particular expertise in materials research and may become more competitive in DoD research competitions, while a nearby institution in the same state may focus on medical research and, therefore, may be more likely to win NIH grants.

Consequently, each agency's geographic distribution of university research funding is not only affected strongly by its mission, but it is also affected by local university and state decisions to develop research capacity in particular disciplines. NSF's geographical distribution will tend to fill in the areas not funded heavily by other federal agencies, because geographic broadening of the research base is an important part of their national infrastructure mission.

In addition to the diversity in agency missions, in disciplines funded, and in geographic distributions, there is also diversity in the review processes used by different agencies in awarding research dollars. In general, however, when mission considerations must be taken into account along with the scientific or technical merit of the proposed research, most agencies, including DoD, cannot rely solely on an external peer review process for making funding decisions. While external peers can help to judge the merit of the science, they are often not aware of the many facets of projects already supported by a particular agency, or of how a proposed research project might fulfill a specific mission requirement. As a result, the Services and Defense Agencies rely heavily on the recommendations of their scientific program managers who are credentialed experts themselves in scientific or technical disciplines, and who also must be knowledgeable of relevant areas of military systems and operations. In addition, each of the Services and Agencies uses external peers in various advisory and review capacities as the need arises.

The following section describes DoD's merit review process, including the commonalities among the Services and Defense Agencies in soliciting, evaluating and selecting research for funding, as well as aspects unique to each. The individual steps of the process from initial advertisement in the Commerce Business Daily, through evaluation of proposals, are similar to the procedures used by all Federal agencies in letting competitive contracts.

The resulting geographic distribution is described in Section II of this report. The conclusions and general recommendations are provided in Section III. Comments submitted by university members of the DoD-University Forum Working Group on Engineering and Science Education are summarized in the Appendix to this report.

SECTION I: DoD MERIT REVIEW PROCEDURES

COMPETITION IN CONTRACTING

Competitive solicitations and awards have been the cornerstone of DoD's research programs since the creation of its defense research agencies. Adhering to competitive procedures has enabled DoD to attract the best and brightest intellectual talent to the conduct of basic scientific and engineering research for the Department. With the passage of the Competition in Contracting Act, (CICA), (PL. 98-369) in 1984, competitive procurements for virtually all federal acquisitions became law.

The Act stipulates that, in the research arena, competitive selection is defined as the "award of any research proposals resulting from a general solicitation and the peer review or scientific review of such proposal." Some DoD agencies use grant instruments to fund their university research programs. Even though the CICA requirements do not apply to grant instruments, the concept of merit review is applied in the same fashion with research grants as it is in the contract research programs.

ADVERTISING RESEARCH OPPORTUNITIES

In compliance with the law and Federal Acquisition Regulations the Services and Defense research agencies annually publish summaries of their research interests in the form of Broad Agency Announcements (BAA's) in the Commerce Business Daily (CBD). Because CBD space is limited, detailed BAA's are compiled in brochure form and are sent to researchers, sponsored programs officials and scientific and engineering department heads of colleges and universities located in all 50 states.

For special programs, such as DoD's new University Research Initiative (URI), special announcements were placed in the CBD, and detailed URI BAA's were circulated throughout the university community. In all cases, BAA's contain detailed descriptions of each scientific and engineering discipline DoD wishes to support, persons to contact for further information, instructions for preparing and submitting proposals, and proposal evaluation criteria and procedures.

In addition to disseminating formal announcements, DoD representatives make special efforts to advertise research opportunities at technical meetings and research symposia, and at the conferences of higher education associations and special interest organizations such as the National Association for Equal Opportunity in Higher Education (NAFEO), among others.

ASSISTANCE FOR THE PREPARATION OF PROPOSALS

In order to attract new people and institutions and the fresh ideas they represent, the scientific program managers of the Services and Defense agencies assist researchers unfamiliar with DoD research interests and management procedures. Researchers requesting additional information beyond that contained in the BAA's on the preparation of proposals, are encouraged to contact the individual Service and agency scientific program managers who guide DoD's research programs.

Interested researchers typically will write, telephone or approach DoD program managers at technical meetings or research symposia. These interactions help potential proposers to decide whether their ideas coincide with DoD research needs. In instances where the ideas do not initially "fit" DoD programs, the potential proposer may, with the information provided by a research administrator, modify his or her approach to accommodate DoD needs.

Assuming this is done, the researcher sometimes is encouraged to submit a two or three page pre-proposal for conceptual review. This "pre-review" is conducted by the appropriate scientific program manager, often with the assistance of an outside technical expert and staff in DoD laboratories. If the evaluations are positive, the researcher is encouraged to submit a formal proposal. If not, suggestions are offered for pre-proposal modification and subsequent re-submission.

This process is designed to help researchers prepare proposals that are more directly supportive of DoD research needs, and therefore, are more likely to succeed during the formal evaluation process.

EVALUATION OF PROPOSALS BY DoD RESEARCH ORGANIZATIONS

Given the similar objectives of the DoD research agencies, there are also common elements to their proposal review procedures.

In general, DoD basic research programs support work which increases understanding at the frontiers of science. Resulting scientific and engineering advances enable the Services to make informed decisions about proceeding with follow-on development activities. Specific proposal evaluation criteria are employed to determine whether a proposal meets these overall objectives.

These criteria include:

- scientific merit and technical approach
- DoD relevance
- extent to which proposed work represents "new" science

- qualifications of the proposed researchers
- adequacy of institutional research infrastructure to support the research proposed
- realism of the proposed costs as compared to proposal objectives

The demands of the evaluation process, therefore, require that DoD scientific program managers maintain expertise not only in scientific disciplines, but also in relevant areas of military systems and operations. As leaders in their respective fields of science and enginering and as consultants to DoD's technology development programs, DoD's scientific program managers are exceptionally qualified to communicate DoD mission requirements to the academic community, and to establish university research programs that are scientifically and technically sound, and DoD-relevant.

In particular, the DoD award process must take into account considerations of both technical quality and relevance to well-defined missions of the Services. Funding decisions often require a balance between these criteria. On the one hand, proposals embodying excellent, but non-DoD-relevant, science cannot be approved for funding. Conversely, work addressing DoD-relevant research issues in technically inferior ways cannot be supported. DoD research administrators having the responsibility for funding decisions in this complex R&D management environment are consequently held accountable from the standpoint of a) quality of the research output, and b) its potential for transitioning into technology which will strengthen the capabilities of the respective Services. This degree of accountability and the need to weigh both scientific opportunity and DoD relevance are the key factors underlying the programmatic decisions of DoD research administrators.

As with pre-proposals, there are a variety of mechanisms that may be employed for the evaluation of formal proposals. These mechanisms reflect the impact of the factors cited above and may be highly structured or not as circumstances or procedures dictate. Review options employed for individual proposals typically depend upon such factors as:

- the relative availability of appropriate technical reviewers within DoD, in universities, industry, and other federal research agencies.

- the extent to which a proposal relates to a specific DoD mission or concept which is in an exploratory or advanced development phase; where this is the case, evaluations are sought from R&D managers who are responsible for concept development oversight, or from operations specialists familiar with the relevant mission and its requirements.

In addition to the general procedures common to the Services and agencies described above, evaluation procedures specific to the three Services and the Defense Advanced Research Projects Agency (DARPA) follow.

ARMY

The Army Research Office (ARO) is the principal Army source of basic research funds for universities. Proposals are initially screened by ARO scientific program managers to determine their relevance to Army research interests. Those found to be appropriate are subjected to two forms of evaluation simultaneously:

a) Scientific or technical merit is assessed by experts selected under the auspices of the National Research Council (NRC) of the National Academies of Science and Engineering. NRC is under contract to ARO to establish Technical Committees in research areas of interest to the Army. The Committees are composed of nationally recognized scientists and engineers. Committee members are given the responsibility for choosing reviewers for individual proposals, for summarizing the results of the reviews, and for assigning a corresponding letter grade to each proposal.

b) While this review process for scientific and technical merit is being conducted, scientists and engineers in Army laboratories, who are experts in the field, review proposals for their technical content and relevance to Army R&D interests.

Given the results of both evaluation procedures, ARO research administrators, who are experts in particular scientific and engineering disciplines as well as military applications, select projects to be supported in light of available funding and overall program balance.

NAVY

The Office of Naval Research (ONR) is the sole source of basic research funds in the Navy and funds the majority of its university R&D. ONR has a long and successful tradition of dependence on highly competent scientific officers for program direction and proposal selection. ONR staff also solicit the advice of defense laboratory and development systems specialists, systems commands, and outside technical experts, both for the evaluation of individual proposals, and for broader programmatic reviews. With respect to the latter, review panels have been constituted through the National Academy of Sciences to provide

advice on the most opportune research directions in virtually all fields of science and engineering relevant to the Navy mission. Within ONR, scientific officers are required to justify proposal selections before a Research Advisory Board composed of senior research administrators. These and other corporate-level program review measures are undertaken by ONR to ensure that appropriate external and internal inputs are factored into the management of its research programs, and into the consequent allocation of Navy R&D resources.

AIR FORCE

The Air Force Office of Scientific Research (AFOSR) has cognizance over all Air Force basic research, and funds the great majority of its university R&D. The Air Force proposal review process emphasizes programmatic flexibility and responsiveness. This approach facilitates the selection of innovative proposals from new investigators and/or institutions that might not possess the credibility to survive a highly structured external review process.

Scientifically expert AFOSR Program Managers have the ultimate responsibility for incorporating the advice of technical experts in universities, industry, other Air Force components and federal research organizations into proposal funding decisions. In all cases, expert advisors are chosen on the basis of their demonstrated scientific and technical expertise. Several of the AFOSR Scientific Directorates have established panels or boards to provide advice on general program direction as well as on individual proposals. Persons serving in this advisory capacity are also selected using the foregoing criteria. The decisions of scientific program managers are reviewed by the scientific director in the chain of command, and if the grant or contract exceeds a certain dollar threshold, by the Commander of AFOSR.

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY (DARPA)

In general, a successful proposal must address itself to a DARPA program area or area of interest within DARPA's purview. Proposal evaluation and associated award decisions are based on a competitive selection process resulting from a peer and/or scientific review. In evaluating a proposal, DARPA requires answers to the following questions:

a) What is the relationship between the technical objectives of the initiative and the current state-of-the-art?

b) In what ways is the technical approach unique, and why do the unique features make it an attractive opportunity?

c) When are the results expected, and what are the projected costs of the program?

d) What benefits would accrue to DoD from a successful program?

Proposals submitted in response to DARPA Broad Agency Announcements are handled by the director of the appropriate technical program; for example, for university investigators, this is typically the Defense Sciences Office or the Information Science and Technology Office. When an innovative idea does not fit within a single technology, the Deputy Director of Research convenes a committee to evaluate it. If found to merit further consideration, the proposal is assigned to the most appropriate office.

A further aspect of DARPA's modus operandi is pertinent: in most instances, a DARPA contract is co-monitored with the participation of a scientific officer from another defense research agency such as AFOSR, ARO or ONR. Moreover, actual contract negotiation and further review are carried out by that agency, and so DARPA awards must pass the same stringent approval processes which apply to that agency's own awards. In a sense, then, DARPA contract awards are "doubly justified."

PROPOSAL EVALUATION FOR SPECIAL PURPOSE PROGRAMS

Review procedures for such special purpose initiatives such as the University Research Instrumentation Program (URIP) or DoD's new University Research Initiative (URI) tend to be more structured than is the case for traditional single-investigator, single-discipline projects which tend to be smaller (averaging approximately $100,000).

URIP

URIP was a five-year, $150 million effort to upgrade university science and engineering research instrumentation. A single solicitation, incorporating the requirements of the three Service research offices, was prepared to announce the URIP competitions for FY 83, FY 84-85, and FY 86-87. Evaluation panels composed of Service experts in scientific and engineering disciplines reviewed the 5,900 proposals which were received in the competitions; 1,065 awards were made to 170 universities in 49 states and the District of Columbia.

URI

The URI program, as another example, was designed to support and encourage multidisciplinary research in support of critical DoD technologies; facilitate contacts among university, industry and DoD laboratories; increase the number of science and engineering graduate students in disciplines important to DoD; and, as URI was phasing in as URIP was phasing out, to increase the investment in major items of research instrumentation at universities.

The design of URI was a cooperative process among the Services, DARPA and the Office of the Secretary of Defense. The Services and DARPA identified a number of broad technologies considered essential to future defense capabilities and selected aspects of these broad technologies to emphasize in their respective URI programs. For example, while research in fluid dynamics is important to both the Navy and Air Force, the Navy chose to emphasize hydrodynamic aspects, while the Air Force concentrated on aerodynamic aspects. These topics were reviewed by a DoD-wide URI Steering Committee composed of senior representatives of the Services, DARPA and the Office of the Secretary of Defense. The Steering Committee was formed to facilitate DoD-wide coordination among participating defense research agencies.

As noted earlier, URI competitive areas were then announced in the Commerce Business Daily, and both DoD-wide and Service and DARPA-specific brochures were distributed to academic institutions in all 50 states. Each BAA contained an introduction to the program, research topic descriptions focused by specific Service/DARPA requirement, information on proposal preparation and submission deadlines, and the criteria against which proposals would be evaluated.

The Services and DARPA assembled evaluation panels to review proposals in their respective technology areas. Forty-five review panels, each composed of between five and ten technical experts, read and ranked the 965 proposals received into "highly recommended," "acceptable" and "not recommended" categories. The panels selected 165 as "highly recommended" finalists and made 163 site visits. Two were not visited due to the fact that they had recently been site-visited.

Approximately 80 percent of the panel members were from DoD, about 17 percent were from other Federal agencies or the private sector (primarily industry), and the remaining three percent were from universities. In considering this distribution it is important to recognize that because of the large proposal response (nearly 1,000) it was very difficult to find university panel members who were both expert in the areas of concern and who had not themselves submitted proposals, and hence were without conflict of interest. After the site visits, the panels prioritized the proposals in each technology area on the basis of their technical merit and their relevance to the respective Service or DARPA mission.

Program selection boards for each Service and DARPA produced a final prioritized list within each technology. These boards took into account the technical prioritization of the review panels and also considered the needs of the Service or DARPA, such as the need to cover adequately the full breadth of each technology advertised in the BAA. Representatives of the Services and DARPA coordinated their efforts through the URI Steering Committee described earlier. Award recommendations by the Service and DARPA selection boards were reviewed by the top management of the Services and DARPA, and ultimately by the DoD-wide Steering Committee.

This committee, chaired by the Deputy Under Secretary of Defense for Research and Advanced Technology, assembled the lists submitted by the Service and DARPA program selection boards and evaluated this integrated package in the context of the total DoD URI program, taking into account the mission and purpose of URI as articulated to Congress. Of the 165 proposals originally ranked highly recommended, funds were available to make 86 awards.

SECTION II: POTENTIAL FOR GEOGRAPHIC EXPANSION

To analyze the potential for expanding DoD's research base into geographical areas which at the present time receive little funding first requires an understanding of the current distributions of R&D funds. A few questions immediately come to mind:

o How does DoD support for research fit within the context of federal support for research as a whole?

o What percentage of federal research does DoD fund?

o How does DoD's mission affect the selection of disciplines for support? Are other agencies similarly affected by their missions in choosing the disciplines they support, and does this in turn affect the geographical distribution of research funding?

o How do decisions made locally by universities and states affect their ability to compete for federal R&D funds?

o Do the federal R&D agencies return R&D funding to the 50 states in amounts which bear some reasonable correlation with state populations or with federal taxes paid by the states?

o Is there a reasonable correlation between the geographical distribution of federal R&D funding and the geographical location of university scientific and engineering Ph.D.'s? Is DoD's geographical distribution comparable to that of other federal agencies?

o If it is desirable from the standpoint of national science policy to alter the current geographical distribution of federal university R&D funding, what changes make the most sense given the complementary diversity in federal university R&D support, current geographical distribution, state and local capabilities, agency missions, and budgetary constraints?

In answering these questions, it is important to keep in mind that the geographical distribution of DoD research funds is the result of the competitive process described in Section I: DoD awards contracts for performing university research through a competitive process which evaluates the merit of proposals against the two primary criteria of scientific and technical excellence, and relevance to the DoD mission.

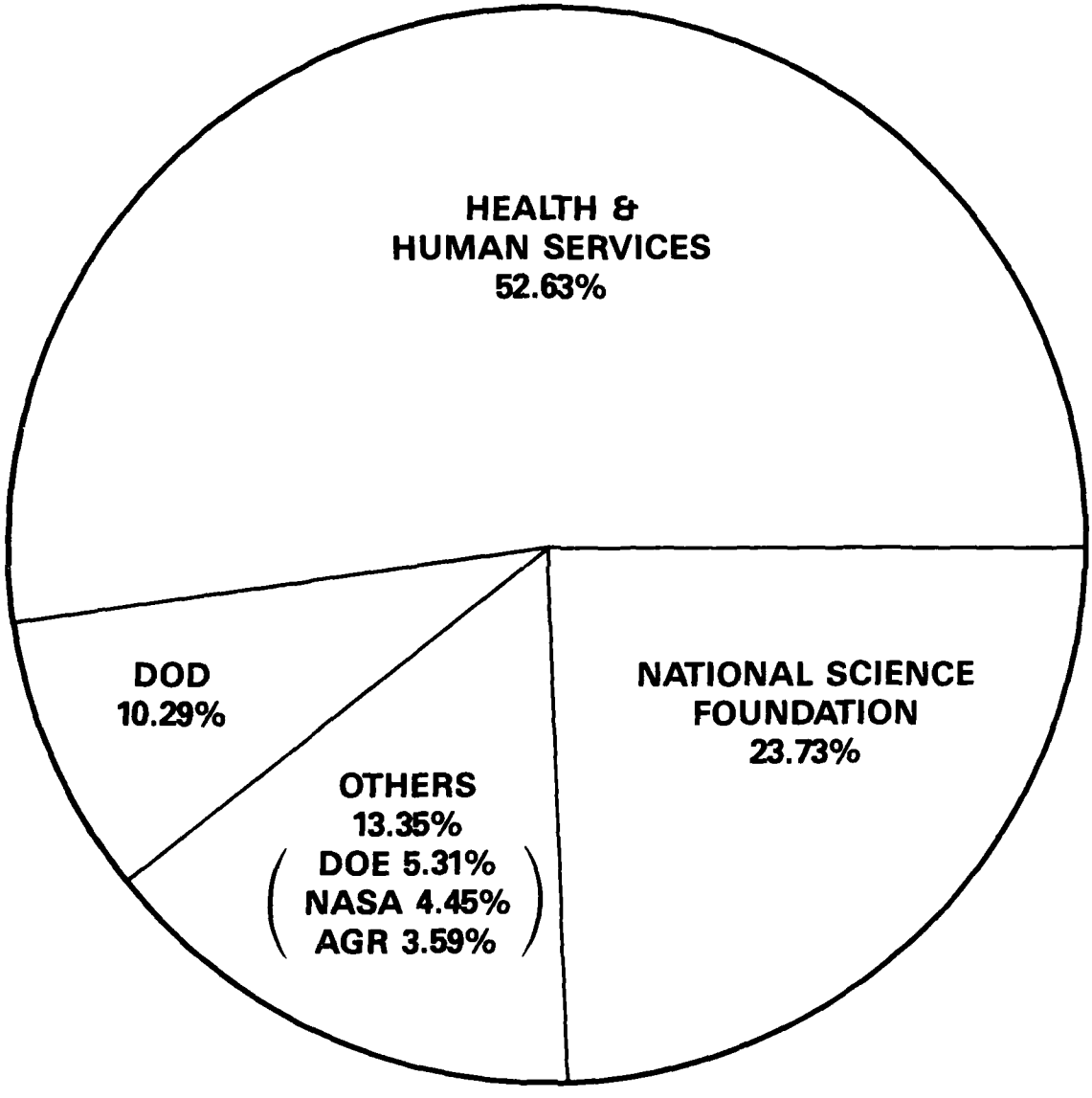
Overall, this competitive process has been used since the formation of the Office of Naval Research in 1946 and the subsequent establishment of the Army Research Office, the Air Force Office of Scientific Research and the Defense Advanced Research Projects Agency. It has resulted not only in revolutionary defense achievements, but in scientific advances that have profoundly benefited the civil sector as well.

FEDERAL AGENCY SUPPORT FOR RESEARCH

DoD is one of several federal agencies which support scientific and technical research. As illustrated in **Figure 1**, the principal federal organizations supporting scientific and engineering research at universities are the Department of Health and Human Services, the National Science Foundation, the Department of Defense, the Department of Energy, the National Aeronautics and Space Administration, and the Department of Agriculture (in descending order of funding).

The Department of Health and Human Services and the National Science Foundation provided more than 75 percent of all the federal support for basic scientific and engineering research at the nation's universities in FY 85. DoD provided about 10 percent of federal support for university research.

FIGURE 1:
BASIC RESEARCH FUNDS AWARDED TO UNIVERSITIES BY FEDERAL AGENCIES (FY 85)



SOURCE: NATIONAL SCIENCE FOUNDATION.

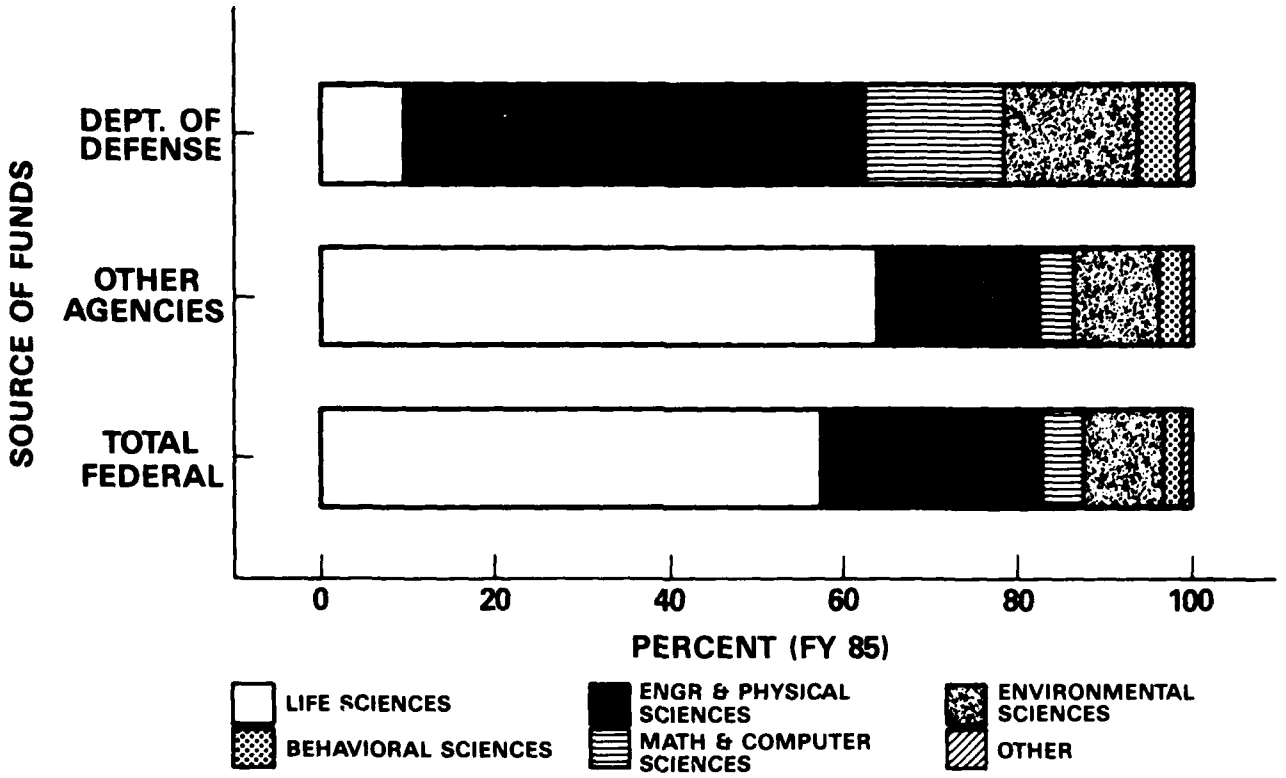
DISTRIBUTION OF FUNDS BY DISCIPLINE

Figure 2 shows federal agency funding to universities by discipline for basic research. As might be expected, with HHS supporting over half of the basic research in the nation's universities, an examination of the distribution of research funds by discipline (Figure 2) shows that the life sciences receive over half of federal research funds.

In contrast, DoD's distribution of funds by discipline is significantly different from that of other agencies. Although DoD does support some research in the life sciences, over 50 percent of DoD's funding is concentrated in the physical science and engineering disciplines related to mission needs.

Similarly, other mission agencies such as DoE, NIH and the United States Department of Agriculture will reflect their differing mission requirements in their patterns of distribution of research funds by discipline. NSF, which has as its mission increasing the nation's base of scientific knowledge and strengthening the ability to conduct research in all areas of science and engineering, will reflect this mandate in its broad distribution of support across all science and engineering disciplines.

FIGURE 2:
BASIC RESEARCH FUNDS TO UNIVERSITIES BY FIELD OF SCIENCE



DISCIPLINE	DOD (PERCENT)	OTHER AGENCIES (PERCENT)	ALL FED AGENCIES (PERCENT)
LIFE SCIENCES	9.5	63.6	58.1
ENG & PHYS SCIENCES	50.8	22.1	25.0
MATH & COMP SCIENCES	16.3	3.0	4.4
ENVIRONMENTAL SCIENCES	16.0	7.4	8.3
BEHAVIORAL SCIENCES	4.6	3.1	3.2
OTHER	2.8	0.8	1.0
	100.0	100.0	100.0

SOURCE: NATIONAL SCIENCE FOUNDATION.

STATE STRENGTHS

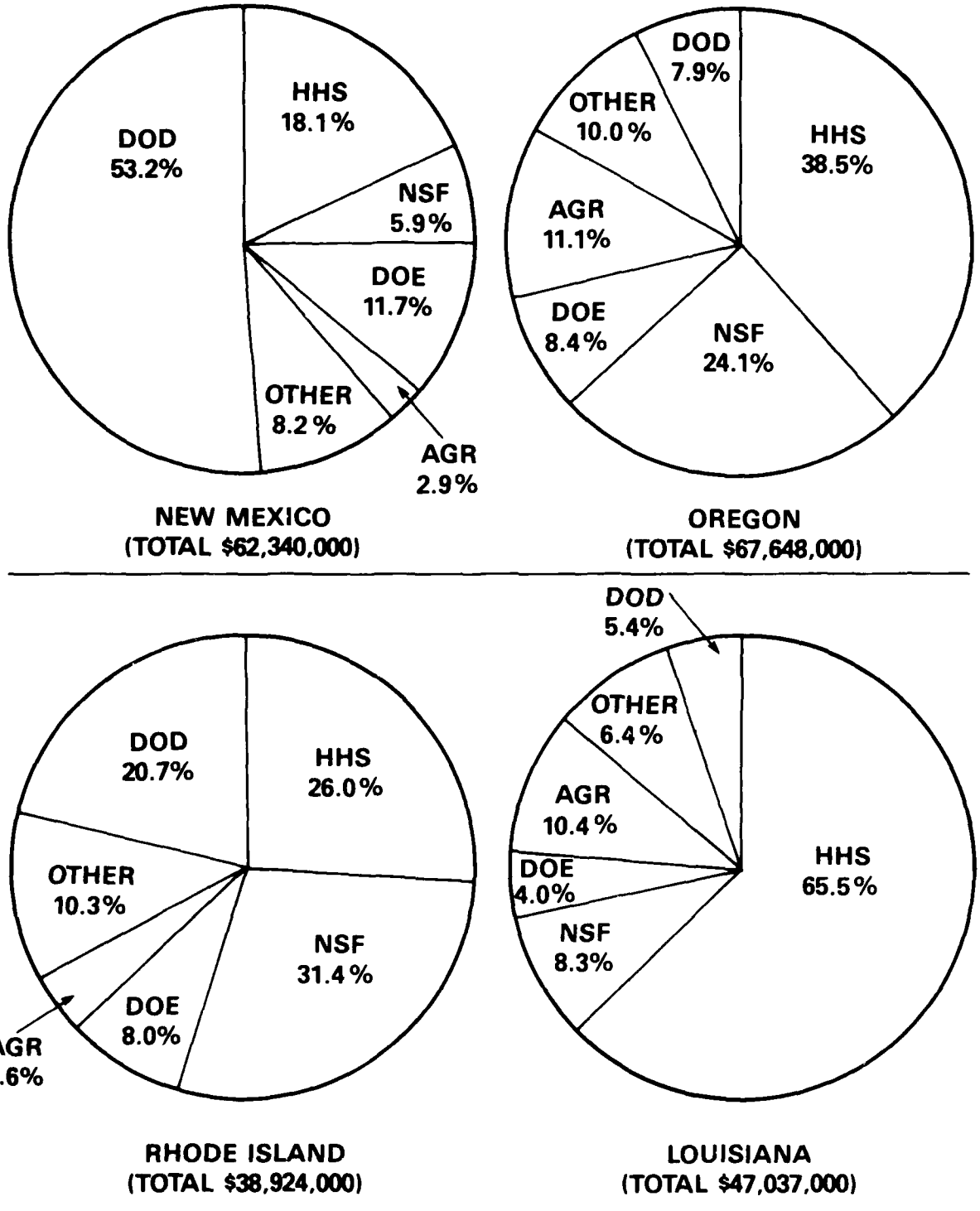
The geographic distribution of federal R&D* funding also appears to be affected by decisions made locally by states and universities to develop expertise in selected disciplines, resulting in states having varied scientific and technical strengths. Such strengths enable states to be more competitive in some disciplines than others, and therefore, to be more likely to attract predominantly more R&D funding from one federal agency versus another.

Figure 3 illustrates how diversity in scientific and technical capabilities locally may affect the distribution of federal R&D support. For example, New Mexico and Oregon received roughly comparable amounts of federal R&D funding, but the percentages each received from various federal agencies differed considerably and are reflective of differing state strengths in disciplines important to the missions of the funding agencies. Contrasts are also apparent for Rhode Island and Louisiana which received comparable total federal R&D funding, but different fractions from the various agencies.

That such diversity is more the rule than the exception is evident in **Table I**, which presents for each state the percentage of its R&D funding from each major federal agency.

*In contrast to material presented earlier in this section which focused only on basic research, the analyses which follow in the remainder of this section are based on figures for all university research and development (R&D) funding. In addition to basic research, DoD relies on the universities for other aspects of its development, test and evaluation program. Approximately 15 percent of all federal university R&D is provided by DoD.

FIGURE 3:
COMPARISON OF RELATIVE R&D FUNDING TO UNIVERSITIES BY AGENCY FOR SELECTED STATES (FY 85)



SOURCE: NATIONAL SCIENCE FOUNDATION.

TABLE I

FEDERAL SOURCES OF R&D FUNDS TO UNIVERSITIES (FY 1985)

	%DoD	%DOE	%NASA	%USDA	%HHS	%NSF	OTHERS
AL	6.2	2.2	7.5	9.9	68.0	3.9	2.4
AK	6.7	3.0	14.1	8.9	1.5	51.9	14.0
AZ	15.2	1.6	13.3	5.1	37.0	24.3	3.5
AR	6.2	1.7	.8	46.2	26.9	10.9	7.2
CA	20.3	5.9	5.7	1.5	47.3	18.2	1.1
CO	11.9	5.3	8.2	4.1	42.9	20.2	7.4
CN	7.0	5.3	.5	1.3	75.3	9.5	1.1
DE	10.2	8.5	1.7	15.3	21.2	35.6	7.6
FL	18.5	10.6	2.8	7.5	39.8	17.6	3.1
GA	27.7	3.7	3.4	8.1	41.9	11.8	3.4
HI	9.3	5.4	18.0	10.1	22.2	22.2	12.9
ID	4.8	3.4	3.4	55.2	5.2	10.3	17.6
IL	14.1	7.0	3.5	3.1	46.9	23.7	1.7
IN	6.2	10.3	2.8	7.4	39.6	32.1	1.5
IA	9.3	.7	6.1	9.5	63.8	8.7	1.9
KS	8.1	4.8	5.5	14.3	51.2	14.0	2.1
KY	2.6	7.4	1.6	33.7	39.9	11.5	3.2
LA	5.4	4.0	1.7	10.4	65.5	8.3	4.6
ME	2.1	4.3	1.4	37.1	5.7	32.9	16.4
MD	29.4	3.9	4.7	2.2	49.5	8.9	1.4
MA	22.5	10.5	4.5	.8	41.4	18.7	1.5
MI	8.0	4.5	4.9	4.9	55.6	19.9	2.3
MN	4.2	5.3	2.2	7.0	62.7	15.7	2.9
MS	9.1	8.3	1.5	40.0	30.2	4.9	6.0
MO	3.4	1.7	2.7	8.1	75.2	7.6	1.3
MT	4.1	4.1	4.1	35.6	16.4	26.0	9.6
NE	3.2	2.5	1.0	20.8	47.7	22.3	2.3
NV	4.1	1.0	4.1	17.5	22.7	16.5	34.0
NH	8.2	1.8	17.7	6.6	51.3	11.1	3.2
NJ	12.0	5.4	3.7	4.5	39.2	31.0	4.2
NM	53.2	11.7	6.9	2.9	18.1	5.9	1.2
NY	13.4	5.3	1.6	1.5	59.3	17.7	1.3
NC	4.2	2.6	1.4	6.3	69.6	11.2	4.6
ND	5.7	4.5	.2	59.6	13.5	5.6	10.9
OH	16.5	2.8	6.3	4.8	53.4	12.7	3.4
OK	11.7	6.1	9.4	17.3	32.9	15.9	6.8
OR	7.9	8.4	1.8	11.1	38.5	24.1	8.2
PA	21.9	4.0	1.8	2.4	54.4	14.2	1.3
RI	20.7	8.0	3.6	3.6	26.0	31.4	6.8
SC	5.0	2.8	1.2	16.2	49.2	22.0	3.6
SD	8.4	3.6	14.3	42.9	8.9	14.3	7.7
TN	5.2	11.9	2.2	7.9	65.5	6.4	.9
TX	10.9	5.0	3.9	5.4	60.6	12.0	2.1
UT	34.0	7.3	3.0	3.1	38.3	12.1	2.1
VT	3.0	.5	.5	9.0	82.1	4.2	.8
VA	8.9	5.3	9.5	8.1	51.8	12.2	4.2
WA	7.9	4.4	1.9	4.7	55.5	18.8	6.7
WV	1.2	5.3	.9	23.7	36.0	4.4	28.6
WI	5.5	9.5	5.9	6.4	54.9	16.4	1.4
WY	2.4	4.2	8.3	23.6	16.7	29.2	15.7

Data Source: Federal Funds for R&D, Vol. XXXV, NSF

GEOGRAPHICAL DISTRIBUTION CORRELATIONS

In order to evaluate the potential for expanding the geographical distribution of federal R&D funds, it is necessary first to understand the factors that currently influence awards. Four factors were reviewed to assess whether they may be used as predictors within the current system. These include: state population; individual and corporate taxes paid to the federal treasury by each state; the number of scientists and engineers at universities in each state; and the number of Ph.D. scientists and engineers in each state. A matrix showing relevant correlations is presented in **Table II**. (A correlation coefficient of 1.000 would signify exact proportion.)

As stated previously, the majority of university R&D awards are made as a result of merit-based competitions inviting scientists and engineers to submit proposals in disciplines relevant to agency missions. The higher correlations associated with technical talent in almost every agency's distribution of R&D funds support the fact that the award of federal R&D funds to universities generally reflects the geographical location of the nation's university-based scientific and technical talent. **Figure 4** shows graphically that the percentage of federal R&D funding received in a given state is more closely correlated with the percentage of the nation's Ph.D. scientists and engineers employed in the state than with the population of the state.

Overall, the distribution of federal R&D dollars correlates well with all the predictor variables tested, including population and federal taxes. There is obviously a great deal of cross-correlation among the variables, with the result that even a pure R&D merit selection process will automatically reflect these other elements to a degree, as well.

Table II also includes correlation coefficients for other federal agencies. The DoD data compare very favorably to those for the other major procurement agencies (DoE and NASA), and also to those of the Department of Agriculture. As expected, the highest correlation coefficients appear for HHS with its substantially greater percentage of federal research funds, and for NSF, with its broader mandate for the support of science.

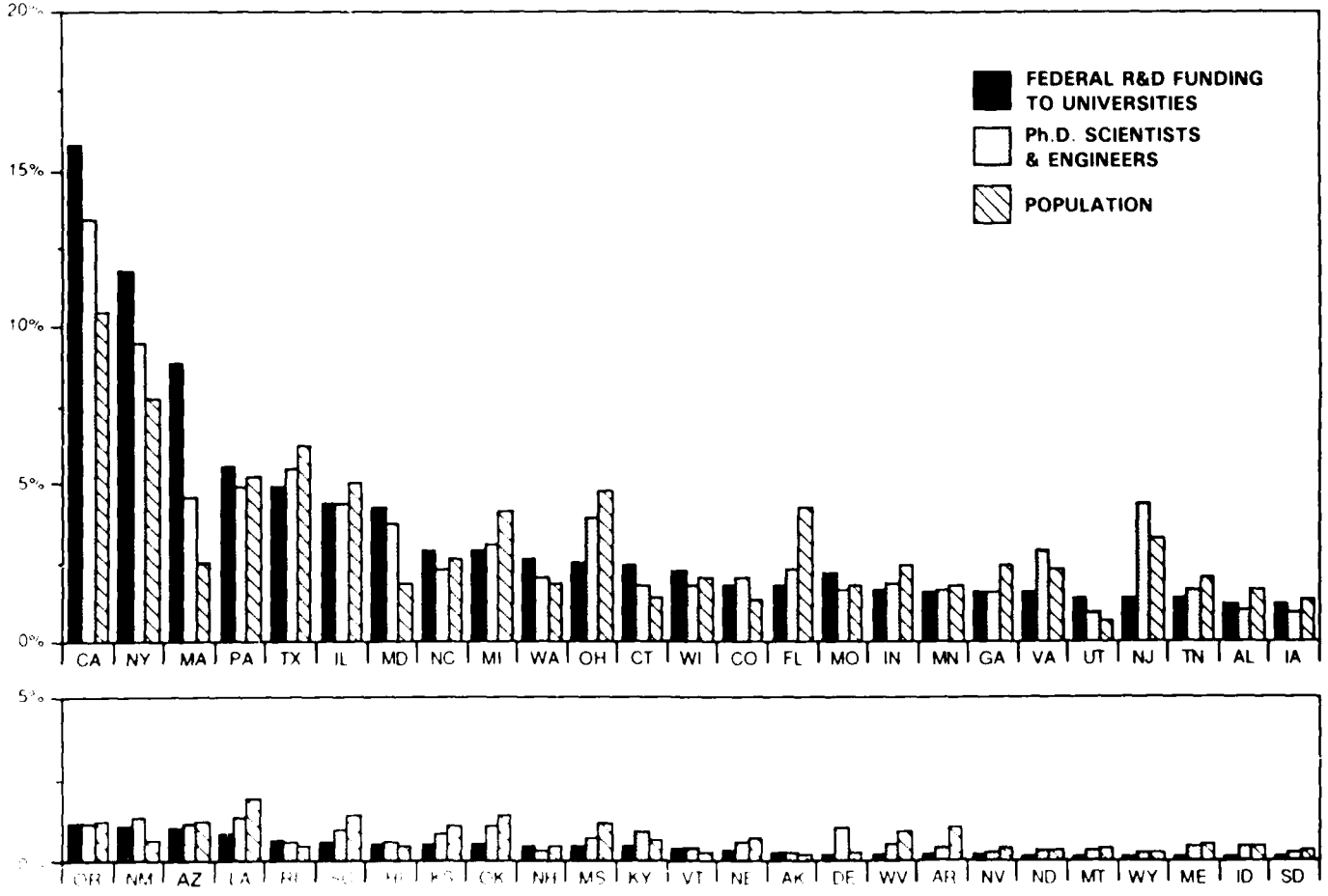
It is reassuring that the competitive approach to contract award, pursued so assiduously by DoD, has not driven awards significantly contrary to considerations of total state population and to considerations of state payments of federal taxes. Despite the favorable DoD findings, possible approaches to achieving still broader distributions of DoD research programs are explored in the remainder of this report.

TABLE II

CORRELATION MATRIX

TOTAL UNIVERSITY R&D FUNDS FROM:	ALL FEDERAL AGENCIES	MAJOR PROCUREMENT AGENCIES			MAJOR SCIENCE AGENCIES		
		DoD	DoE	NASA	USDA	HHS	NSF
VS: POPULATION	0.865	0.753	0.731	0.738	0.773	0.877	0.842
FEDERAL TAXES	0.882	0.767	0.754	0.746	0.718	0.895	0.864
UNIVERSITY S&E's	0.910	0.807	0.828	0.718	0.707	0.926	0.866
S&E Ph.D.'s	0.954	0.882	0.839	0.848	0.645	0.947	0.934

FIGURE 4:
COMPARISON OF FEDERAL R&D FUNDING TO UNIVERSITIES, Ph.D. SCIENTISTS AND ENGINEERS, AND POPULATION



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SUMMARY

In analyzing the potential for expanding DoD's research base, it is helpful to address the following issues: (1) what attributes contribute to the success of many universities in merit competitions for federal and DoD research funding; (2) how might a university develop those attributes in order to establish itself as a research performer; and (3) what kinds of federal research programs might be best suited to address the needs of new research performers?

DoD, along with other federal agencies, awards research funds to institutions on a competitive basis. The Department evaluates the merits of each proposal submitted in response to announcements of DoD research interests, applying selection criteria that are published in the announcement.

The research infrastructure at an institution plays a large role within these selection criteria. The research infrastructure is defined as encompassing a number of quality Ph.D.-level research personnel; scientific instruments needed for production or measurement of experimental specimens; computing resources; adequate technical support staff; and an ongoing supply of quality graduate students on their way to earning Ph.D.'s. This research infrastructure is interwoven fully with the infrastructure for science and engineering education.

Not all of the elements of research infrastructure need be present for every research proposal to achieve success in attracting DoD or other federal funding, but the elements do support each other in ways that make the whole greater than the sum of the parts. For example, adequate faculty expertise, the principal ingredient for research, may exist in some cases, but the faculty may be operating under too great a teaching load or may have inadequate equipment or technical support.

How might an institution develop an infrastructure in order to establish itself as a research performer? There probably is no single formula for success, although the traditional way for most universities has been to attract quality faculty to engage in both research and education in their fields of specialization. As noted above, this expertise is the most important component of the research infrastructure, as these faculty generate the ideas and prepare the proposals for submission to funding sources.

A university can enhance a faculty member's prospects for success in winning a research contract by providing some initial commitment of physical resources, financial assistance or other incentives such as reduced teaching loads and the assignment of graduate students. The successful new principal investigator can then enhance the supporting elements of the infrastructure by using his contract funding for purchasing additional equipment, hiring technical support staff, and attracting other scholars.

In recent years, DoD has significantly increased the support it provides via its research grants and other special programs to assist institutions in developing elements of the research infrastructure. In addition to the URIP program described earlier which provided $150 million over a five-year period to support large instrumentation purchases, DoD research contracts and grants normally provide funds for principal investigators to buy research instrumentation necessary to carry out the research, along with funds to support graduate assistants. All three Services support graduate fellowship programs; summer research opportunities in DoD laboratories for faculty and students; and special focus efforts to assist minority institutions and Historically Black Colleges and Universities in developing strong science and engineering research and related education programs.

Developing a research infrastructure is not an overnight process, but it is one by which universities have "bootstrapped" programs that began as small, single-investigator efforts into recognized centers of expertise in a research area, with concommitantly larger funding. This process is also generally accompanied by a continuing institutional commitment which enhances a researcher's ability to attract continued federal and non-federal R&D funding.

It also appears that single-investigator programs, such as those principally funded under DoD's Defense Research Sciences program, may present the best opportunity for universities to build new research capabilities. Research centers and larger block research programs, such as those funded under URI, are more appropriate if a number of strong research faculty members already reside at a given institution, and if the infrastructure is more fully developed.

If new federal efforts to address the needs of institutions wishing to develop research capabilities are to be explored, there are several factors which should be considered. Among them are the experiences of programs established specifically to build research capability within a state; the role of traditional single-investigator programs in helping to develop an institution's research capabilities; the role of states and the private sector; and the emerging need for research facilities among both established research institutions and newly emerging research institutions. These and other factors are reviewed briefly in the following section, and recommendations for the Committees' consideration are presented.

SECTION III: CONCLUSIONS AND RECOMMENDATIONS

As this analysis has shown, the distribution of federal R&D resources among institutions and states varies depending on the disciplines supported, the federal agencies supporting the research, and decisions made locally by states and universities to develop research capabilities in particular disciplines.

Within DoD, those institutions which have researchers strong in the physical sciences and engineering disciplines important to the defense mission have typically submitted the most competitive proposals and have, therefore, won the majority of research awards congruent with federal acquisition law and regulations.

Should it be desirous from the standpoint of national science policy to alter the geographic distribution of awards for scientific research, then the total scope of federal funding for university research must be taken into account. With each federal agency emphasizing different disciplines, and with each providing varying percentages of the federal research budget, a federal-wide, rather than an agency-specific approach, would appear to be most logical.

Although DoD provides about 10 percent of federal research support to universities, DoD's programs focus on the physical sciences and engineering disciplines, often considered crucial to both industrial competitiveness as well as the nation's defense technological advantage. Accordingly, in any federal-wide planning effort to provide for geographic broadening of the research base, DoD interests should be fully represented.

RECOMMENDATION: The full scope of federal research support should be examined, together with individual agency mission requirements, before any plan to reconfigure geographic distribution of federal research funds is considered. Participants in this process should include the White House Office of Science and Technology Policy, officials of science-intensive agencies, and representatives of the scientific community at large.

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There is an abundance of capability in the university research community as recently evidenced in the FY 1986 URI competitions. Of the 816 non-duplicative proposals submitted, 165 were ranked outstanding and could have produced excellent results had the funds to support them been available. It has been estimated that support for basic research could productively be doubled without compromising quality.

DoD recognizes that some institutions have traditionally received less R&D funding from DoD than they have from other federal R&D sources. A federal-wide approach to capacity-building in these institutions should consider the strengths that these institutions already possess and examine the potential for building new efforts through such approaches as developing single-investigator capabilities.

The important roles to be played by the institutions themselves, the states, and the private sector in developing research capabilities, should all receive consideration in any federal-wide plan for assistance.

As federal budgets are more tightly constrained in a cost-cutting era, care must be taken not to divert funds from highly productive ongoing research efforts. Such diversions would be self-defeating, since the goal should be the expansion of national research capability, not simply its redistribution.

RECOMMENDATION: Any Federal-wide plan to reconfigure geographical distribution of research funding also should assess the current capability of institutions which desire to enhance their level of scientific research in chosen disciplines; the potential payoff for the nation from investment in these disciplines; and the willingness of states and the private sector to cost-share or make comparable investments in building and maintaining the required human and material resource infrastructure.

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Research by its very nature is an endeavor with long-term payoffs that requires patience, as well as persistence. Building new research capability is similarly a gradual process requiring a sustained commitment and stable, multi-year funding to be effective.

RECOMMENDATION: New programs or efforts initiated to help institutions reach a higher level of research capability should be initiated with new money and should be sustained for a minimum of five years so that scientific and technological pay-offs can be realized both for the future competitive capabilities of the institutions, and for return on investment for the nation.

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Programs established to foster the participation of specific populations and states in science and engineering have been ongoing for many years. These include the Minority Institutions Science Improvement Program (MISIP) supported by the Department of Education's Fund for the Improvement of Postsecondary Education; the National Science Foundation's Experimental Program to Stimulate Competitive Research (EPSCOR) program; and DoD's programs with the Historically Black Colleges and Universities.

RECOMMENDATION: In developing a federal-wide plan, the experience of federal programs designed to foster the participation of specific populations in science research should be examined to determine those elements which lead to success, including optimum investment strategies, the length of time required to increase competitive capabilities in science and engineering disciplines, and other factors.

* * * * *

As institutions build research capabilities, they will develop needs for research facilities. The federal government has traditionally played a minor role in building and maintaining facilities required by universities for performing their research and education missions. Numerous recent studies have pointed out that established research institutions also have critical needs in this area.

Any new federal role in this area should consider the facilities and equipmert needs of newly developing research institutions, along with those of established research performers. Several bills have recently been introduced to assist colleges and universities to repair, renovate or replace laboratories and other research facilties.

RECOMMENDATION: Any federal-wide plan to assist institutions to strengthen research capability should take into account the research instrumentation and facilities needs of newly emerging research institutions, as well as the needs of established research performers.

* * * *

The scientific preeminence the nation now enjoys is the result of past adherence to merit principles in the selection of research to be supported. Future advances in science and technology, on which both our economy and defense are based, will depend upon continuing support for the best science and engineering research. Merit evaluation principles should be incorporated in the award of funds for any new program designed to build research capability. Rewarding excellence will help ensure the continued preeminence of America's research universities as the research base is broadened to include a greater number of institutions.

RECOMMENDATION: New federal programs initiated to enhance the capabilities of institutions to perform scientific and technical research should be competitive and should incorporate merit principles in the selection process.

APPENDIX

On January 20 and 21, 1987, the Engineering and Science Education Working Group of the DoD-University Forum was invited to present viewpoints on the subject of DoD's merit review process and the geographical distribution of DoD research funds. Following briefings from the Services and DARPA explaining their merit review processes and resulting geographical distribution, representatives of four federal agencies, the National Science Foundation, the National Institutes of Health, the Department of Agriculture and the Department of Energy, commented on their peer review processes and geographical distribution.

While the proceedings of the meeting are too lengthy to append here, the university members of the Working Group, together with representatives of other universities and higher education associations attending the meeting, were invited to submit their comments on these issues. Their comments can be summarized as follows:

- The university members of the Working Group reaffirmed the general soundness of the present merit review and competitive award systems of the Services and DARPA and suggested that fundamental changes are not needed. They indicated that the diverse natures of the review systems of the Services and DARPA are significant strengthening factors in DoD's research programs, serving the Department well and contributing to the health of the entire Federal research establishment. They recommended that the strengths of the individual systems should be preserved, and that no single model be imposed.

- On the other hand, the university members felt that DoD and other Federal research agencies could do a better job of informing the academic research community and others about the operational aspects of their competitive review and award systems. They cited a lack of understanding in the university community and elsewhere of the origins, purposes, and procedures of the Services/DARPA competitive review and award systems and how these processes contribute to sustaining high quality in DoD's research and technology base. They recommended that DoD, perhaps jointly with other agencies or the DoD-University Forum, develop ways to inform the research community and others about DoD's competitive review and award processes. (The exposition in the first sections of this report should be helpful in this respect.)

- The university participants also surfaced the issue of Congressional set-asides of DoD research funds for specific institutions, suggesting that such earmarkings are having a serious effect on the research programs. It was the opinion of participants that a continuation of the practice would compromise the core research program, threatening the stability of the DoD university research base and the integrity of the merit review and competitive award processes of the Department.

- The university participants felt that the merit-based review and award system had resulted in an equitable geographic distribution of research funds. Should increased funding be available for university research, however, it was recommended that DoD join with other research agencies to coordinate activities to strengthen research institutions in relatively underserved areas. Participants cited the EPSCOR model developed by the National Science Foundation for DoD consideration.

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